INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy

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Sustainable development of a remote community by the exploitation of Low Enthalpy Geothermal Energy – The Case of Milos Island, Greece -

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ABSTRACT

The Greek Island of Milos is constantly facing a very serious drinking water scarcity problem. Some 5,000 permanent inhabitants, and about 85,000 tourists visit the island in the summer months. Both, water demand and the number of tourists increase annually.

GSDP with the objective of improving the water supplies on the island concluded in a sustainable solution that is to desalinate seawater by the means of an innovative low enthalpy geothermal energy driven desalination plant.

The Milos project, funded by the EU DG TREN Contract NNE5-1999-0041, is innovative and very attractive from a technological perspective. Only a small proportion of the geothermal utilisation schemes applied in a worldwide scale up today are combining different technologies in such energy efficient and cost-effective way.

The unit will comprise of:

- *a multi-effect water desalination unit with an installed water production capacity of 75t/h*
- *numerous cascade applications such as ORC electricity production and direct heating and/or cooling applications*
- *a phase of reinjecting the utilized geothermal water after all applications (at 25-30 ^oC).*

The MED desalination method is best suited to the Milos case because of the existing thermal energy input from the low enthalpy geothermal energy that is available on the island and especially considering the weak grid supply of electricity by the Public Powers Utility driven with fossil fuels on the Island which would cause problems to electricity depended desalination methods.

The project will bring several benefits to the remote community of the island of Milos. Water can be used for irrigation. Groundwater levels should be able to recover on a long - term basis. Water bottles should no longer be needed in such extent, in parallel easing the island's garbage problems. Household and industrial equipment involving water will now be using cleaner water, thus reducing the cost for the water itself and the maintenance of the equipment. As a direct consequence an increase in the overall employment rate is anticipated followed by a general amelioration of the quality of life.

GSDP plans to replicate the project on at least four other islands in the region. These projects will begin by producing drinking water and then scale up providing other supplies like heating, cooling and cleaner energy. The new projects should benefit from the experience and contacts gained on Milos. Several areas in the Mediterranean, and elsewhere, lack fresh water but have geothermal energy potentials, and could make use of the innovative technology that is being developed and tested within this European project.

TECHNICAL DETAILS

The cascade utilization scheme will comprise of:

- An organic rankine cycle (ORC) unit with an installed capacity of 400 KW,
- a multi-effect water desalination unit with an installed water production capacity of 75t/h,

- Cascade space heating/cooling units
- Reinjection of geothermal water

A geothermal water flow of an estimated T<100ºC with a flow-rate of 250 m^3/h is brought to two successive heat exchanging stages. The first heat exchanger drives the ORC-unit while the second the multi-effect water desalination plant.

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The main operating principle of the unit is as follows:

A geothermal water flow of an estimated T~100ºC with a flow rate of 250t/h (equal to 751/s) is brought to two successive heat changing stages, through Heat Exchangers 1 and 2 (HE 1 and HE 2). HE I drives the ORC Turbogenerator unit and HE 2 the Multi-effect water desalination plant.

A scheme of the concept is reported in Figure 1, which shows the connections of the turbogenerator to the geothermal hot water and to the cooling water.

The HE 1 operates at a Primary Geothermal Circuit temperature of approximately

T = 98-100 ºC with a flow rate of 280 t/h providing the required energy to the secondary closed circuit (evaporator of unit), increasing the temperature of the secondary flow with a quantity of energy capable of driving the ORC plant.

At the HE2 the geothermal water flow provides its energy through the reduction of its temperature from 78º C to 50º C, providing the necessary energy for the operation of the Multi effect water desalination plant (first effect of distillation at >75º C). Part of the sea water is evaporated under vacuum in the first flash effect and consequently in the following distillation/boiling effects. The vacuum makes it possible to lower the boiling temperature and thereby minimize the amount of energy necessary for evaporating the feed water, and furthermore the low boiling temperature prevents deposits of scale inside the tubes.

The heat from the geothermal energy is transferred by means of a plate heat exchanger (HE) into the seawater, which in turn is introduced into the desalination train that is in a vacuum state (sub-atmospheric pressures). The unit will be designed to produce **75 m^3** of fresh desalinated water per hour during the Summer period.

The geothermal water flow after the Heat Exchanger Stage 2 outlet is brought to further applications for space heating and cooling and finally to the reinjection well at an estimated temperature 25-30º C.

The total energy provided by the geothermal system to the ORC-MED plant (HE 1 - HE 2) estimated to be in the order of 12-13 MWth and for the Space Heating and Cooling units 5-6 MWth.

DISTILLATION PRINCIPLE

The proposed MED-Vertical Tube distillation method is based on the multi-effect distillation rising film principle at low evaporation temperatures (less than 80°C), due to the reduced pressure (almost vacuum). The rising film principle takes advantage of the fact that the inner tube surfaces are always covered with a thin film of feed water that prevents scale formation. The working principle is as follows:

The vapour forms a column around the tube center which presses the feed water against the tube surface ensuring a continuous thin film of water on the tube surfaces hereby eliminating dry spots where scale may deposit.

A controlled amount of sea feed water is led into the bottom of each effect and into the tubes in the heat exchanger, where the low enthalpy geothermal energy in the form of hot water of less than 80 °C, as the heating medium, heats it up.

Part of the sea-water is evaporated under vacuum, which is created by means of water ejectors connected to each effect. The vacuum makes it possible to lower the boiling temperature and thereby minimizing the amount of energy necessary for evaporating the feed water, and furthermore the low boiling temperature prevents deposits of scale inside the tubes.

The vapour generated in the first effect passes a separation compartment where the remaining feed water droplets are separated from the vapour and are extracted with the brine. The separated vapour leaves the first effect and flows through the vapour connection pipe to the heat exchanger in the second effect, and the vapour is now used as the heating medium for the second effect. Brine extracted from the first effect is mixed with sea feed water and is brought to evaporation by means of the heat from the vapour generated in the first effect. This process is repeated in the second, third, fourth etc., when these occur.

The vapour used for heating of the second, third, fourth etc. effects condenses on the outside of the heat exchanger tubes, and flows through the flash pipe in the bottom of the heat exchanger into the flash tank. Separated vapour from the third effect is led into the condenser where it is condensed on the outside of the condenser tubes in which sea cooling water is flowing. The condensate flow down into the flash tank at the bottom of the condenser. The condensate is extracted from the flash tank by the freshwater pump and is pumped into the fresh-water tank.

FINANCIAL FEASIBILITY – ENERGY SAVING – ENVIRONMENTAL PROTECTION

Through the application of the previously mentioned cascade utilization scheme the following benefits (financial, energy saving/substitution and environmental) will be achieved see the following table:

DESALINATED WATER PRODUCTION	Nominal 1800 m^3/day Average 1350 m^3/day
COST OF CUBIC METER OF DESALINATED WATER	Approx. 1,64 EURO
ENERGY SAVING OR SUBSTITUTION FROM ORC-MED UNIT	10.672,97 TOE
REDUCTION OF CO_2	34.153,49 TCO_2
REDUCTION OF SO_2	227,15 TSO_2
ENERGY PRODUCTION COST FOR SPACE HEATING/COOLING	0,032 EURO/kWh_{th}
ENERGY SAVING OR SUBSTITUTION FROM SPACE HEATING/COOLING	4.200,00 TOE
REDUCTION OF CO_2	13.440,00 TCO_2
REDUCTION OF SO_2	89,39 TSO_2
TOTAL REVENUES	1.100.000 EURO/year

CONCLUSIONS-IMPLICATIONS

As previously mentioned GSDP plans to replicate the project on at least four other islands in the region. These projects will begin by producing drinking water and then scale up providing other supplies like heating, cooling and cleaner energy. The new projects should benefit from the experience and contacts gained on Milos. Several areas in the Mediterranean, and elsewhere, lack fresh water but have geothermal energy potentials, and could make use of the innovative technology that is being developed and tested within this European project.

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